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PROGRAM TO DEVELOP HIGH STRENGTH  
ALUMINUM POWDER METALLURGY PRODUCTS.  
PHASE IV. SCALE-UP TO 3200-LB. BILLETS

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Prepared for:

Frankford Arsenal

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# Program to Develop High Strength Aluminum Powder Metallurgy Products

## Phase IV - Scale up to 3200 lb. Billets

W.S. Cebulak  
Fabricating Metallurgy Division  
Alcoa Laboratories



Seventh Quarterly Report  
December 20, 1973 to March 19, 1974

U. S. Army Frankford Arsenal  
Contract DAAA25-72-C0593

A Department of the Army Manufacturing  
Method and Technology Project

D D C  
R E P R O D U C T I O N  
JAN 30 1975  
R E U S E L I M I T E D  
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ALCOA

December 5, 1974

U. S. ARMY  
FRANKFORD ARSENAL  
CONTRACT DAAA25-72-C0593

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SEVENTH QUARTERLY REPORT

For the Period December 20, 1973  
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### SYNOPSIS

Cracking of the 3100 lb isostatic compact due to water leaking into the rubber mold and the low compact strength led to a process revision. Vibratory powder packing in the vacuum preheat container will replace cold isostatic pressing prior to encapsulation for vacuum preheating.

Eight lots of powder were produced for powder billet fabrication, four lots each in MA87 and MA67 alloys. Vacuum can design was developed to maximize the powder weight in the hot compacting tools. By vibratory packing, powder density was raised from 45% to 59% of theoretical density.

An evacuation line pinch-off tool was designed, constructed and successfully used to close 2-in. aluminum pipe.

All the steel forgings for the hot compacting tools were received. Finish machining of components was in progress.

FOREWORD

This progress report was prepared for management purposes. It is a preliminary report of information generated during the seventh quarter of this investigation. The data and conclusions reported may be subject to major change. This report will be replaced by a summary report.

## INTRODUCTION

This manufacturing method development program, initiated under Contract DAAA25-70-C0358, is intended to scale-up an aluminum powder metallurgy wrought product fabrication process that yields mill products (e.g., plate, extrusions, forgings) capable of superior combinations of high strength, stress corrosion cracking (SCC) resistance and fracture toughness compared to commercial ingot metallurgy alloys.

Specific property objectives as stated for extrusions are as follows:

<u>Property</u>	<u>Target A</u>	<u>Target B</u>	<u>Target C</u>
Longitudinal Y.S.	95 ksi	85	75
Longitudinal $K_{Ic}$	26 ksi $\sqrt{\text{in.}}$	26	45
Transverse Stress w/o SCC	25 ksi	25	42

Achievement of these targets was demonstrated on laboratory scale P/M wrought products and reported in the third and fourth quarterly reports<sup>1,2</sup> of this program.

This report presents the work accomplished in the seventh quarter of this contract, with some reference to progress reported in earlier quarterly reports.

During the seventh quarter, the following specific items were subjects of activity and are discussed.

### Scale-Up to 3200-lb Billet

1. Examination and analysis of cold isostatically pressed compact.
2. Alternate process selection.
3. Powder production.
4. Vacuum system design.
5. Hot compacting tool construction.

### PROGRESS IN THE SEVENTH QUARTER

#### Scale-Up to 3200-lb Billets

As mentioned briefly in the Sixth Quarterly Report, the 3100-lb MA87 alloy cold isostatic compact cracked due to reaction of the

compact with water that leaked past the top seal. This compact is shown in Figure 1.

While the probable cause for this water leak was not exactly pinpointed, it was felt that a vacuum generated under the upper cylinder seal as it was lifted from the cylinder lifted the top rubber seal from the main isostatic rubber container to allow air in the bag to escape to the vacuum. This opening then allowed water to enter the isostatic container when atmospheric pressure was restored.

This compact achieved 69-71% of theoretical density in cold isostatic pressing at 16 ksi, indicating that the compact would be relatively fragile to handle.

After encountering this obvious problem with sealing of large cold isostatic rubber molds, consideration of alternate approaches to powder handling began. Since a green compact would require encapsulation for vacuum preheating, one possible alternate was to abandon the cold compacting step completely and directly encapsulate powder in the vacuum preheat container. This procedure would eliminate the development work required for cold isostatic compaction, and would eliminate one step in the production operation, potentially decreasing the cost of the end product.

In earlier work with 20-lb billets, the fracture toughness achieved for extrusions from vacuum preheated and vacuum hot pressed powder was comparable to the fracture toughness of extrusions made from vacuum preheated and vacuum hot pressed isostatic compacts.

One difficulty with this alternate was that the hot compacting tools had been designed and were being constructed for a 70% dense powder compact of 44,000 cu. in., while as-atomized powder has an apparent density of 45% of theoretical density. This lower density would mean that the hot compacting tools as designed could make only a 2000-lb billet. To raise the metal weight in the vacuum preheat container, vibratory compaction was investigated to raise the powder density.

#### Vibratory Packing Development

Early trials to develop a vibratory packing procedure used 20-lb charges in six inch welded aluminum cans and a small turbine vibrator. Densities of 55 to 59% of theoretical density were achieved with MA87 alloy powder. Based on these results, a large turbine vibrator was incorporated in a fixture that would be used for vibratory compacting of loose powder in the welded aluminum container used for vacuum preheating. On the basis of these results, the atomization of alloy powders was initiated for fabrication of the large hot pressed P/M billets.

#### Atomized Alloy Powders for Vibratory Compaction

The alloys listed in Table 1 were melted and atomized to the powder sizes shown in Table 2 for vibratory compaction.

### Vacuum System Design

The vacuum can shown in Figure 2 was designed to fit the hot compacting cylinder and maximize the weight of powder for vibratory compaction and hot pressing in the tooling designed for the 3200-lb billet scale-up. It was estimated that vibratory packing would result in 2900 pounds of powder in this can. The can incorporates a 2-in. aluminum evacuation line with a porous stainless steel filter over the inside evacuation-line opening to prevent powder entrainment in the vacuum equipment. Vibration will be used during the entire period of powder loading, to maximize the density achieved within each container.

The preheat system will have three vacuum containers connected in parallel to a vacuum pump system consisting of a 10-in. ring jet booster pump backed up by a Stokes Model 412H mechanical pump.

The evacuation line from each preheat container must be severed from the vacuum system while maintaining the vacuum within the powder container for successful hot compaction. The tooling shown in Figure 3 incorporates a ten ton hydraulic cylinder in a C-frame, with an appropriate set of jaws for pinching a 2-in. ID aluminum pipe evacuation line. With a ten ton load on the 1/4-in. wide x 3-1/2-in. long jaw face, successful complete sealing is accomplished by simply pinching the vacuum line. The procedure for severing of the vacuum line from the vacuum system will require a series of closely spaced pinches combined with melting of the evacuation line at the center of the pinched area. These tools have been successfully tried on live vacuum lines for both hot pinching and for pinching and melting for separation of the vacuum line. The pincher includes the hydraulic cylinder, C-frame, and jaws for a total weight of 57 pounds, which will be counterbalanced on a fixture for accurate placement of the pinching tool during the actual line sealing.

### Finish Machining of Hot Compacting Tools

The components for the lower hot compacting tool system are shown in Figure 4. Figure 4a is the H12 steel liner, while Figure 4b shows one of the two container rings during machining prior to the shrink fit assembly around the liner cylinder. This assembly by hot shrink fitting will be accomplished in the eighth quarter.

The components making up the densification ram assembly are shown in Figure 5. Figure 5a shows the steel nose for the ram which is to be bolted to the punch shown in Figure 5b. The holder for the ram is shown in Figure 5c, and this bolts to the upper hard plate shown in Figure 6, shown as the top hard plate. These hard plates will be bolted to the bare upper and lower platens of the 35,000-ton press at Alcoa's Cleveland Works. Figure 7 shows the lower seal which will be machined to fit the lower end of the hot compacting cylinder. This component will bolt to the lower hard plate to be installed on the bottom plate of the press.

It is expected that assembly of these hot compacting tools will be completed in the eighth quarter of this program.

WORK TO BE COMPLETED IN THE EIGHTH QUARTER

1. Assemble hot compacting tools at Cleveland Works.
2. Design and initiate fabrication of heating system for hot compacting tools at Cleveland Works.
3. Fabricate vacuum system components and assemble into operating vacuum systems at Alcoa Technical Center.
4. Fabricate the aluminum vacuum containers for vibratory packing of powder.
5. Design and fabricate vibratory packing fixture for large turbine vibratory for bolting to the vacuum preheat containers.
6. Complete assembly of the revised jaw design for the evacuation line pinch-off tool to eliminate jaw binding in the tool slide.

REFERENCES

1. W. S. Cebulak, "Program to Develop High Strength Aluminum Powder Metallurgy Products - Phase IVA," Contract DAAA25-72-C0593, June 11, 1973.
2. W. S. Cebulak, "Program to Develop High Strength Aluminum Powder Metallurgy Products - Phase IVA," Contract DAAA25-72-C0593, January 14, 1974.
3. W. S. Cebulak and D. J. Truax, "Program to Develop H. Strength Aluminum Powder Metallurgy Products - Phase III Final Report," Contract DAAA25-70-C0358, September, 1972.

TABLE I  
CHEMICAL COMPOSITION OF ALLOYS ATOMIZED FOR P/M BILLETS

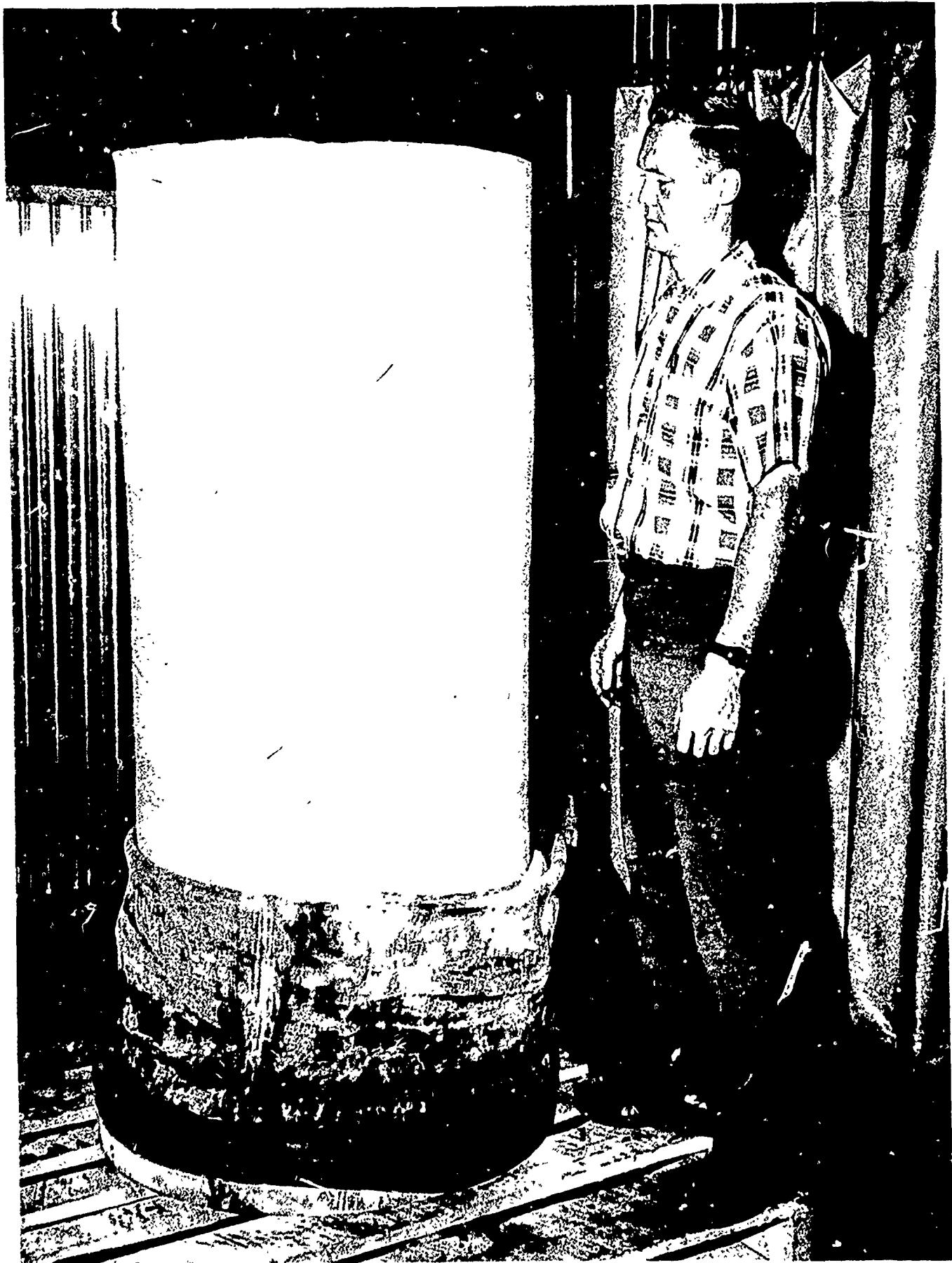
Sample No.	Average Composition - Weight Per Cent						Pot Number
	Zn	Mg	Cu	Co	Si	Fe	
<b>MA87 Alloy</b>							
354107	6.69	2.48	1.65	0.37	0.05	0.05	0.002
354108	6.66	2.52	1.62	0.39	0.05	0.06	0.002
354109	6.46	2.43	1.68	0.39	0.08	0.06	0.002
354110	6.66	2.56	1.69	0.41	0.04	0.09	0.002
<b>MA67 Alloy</b>							
354111	8.00	2.53	1.03	1.56	0.05	0.10	0.002
354112	7.99	2.44	1.01	1.56	0.05	0.08	0.002
354113	8.07	2.58	1.03	1.48	0.05	0.07	0.002
354114	8.26	2.56	1.06	1.54	0.04	0.07	0.002

Notes: Anal. Chem. J.O. 74-011702; -012410; -012801; -021201; -030107;  
-030713; -031304; -031907

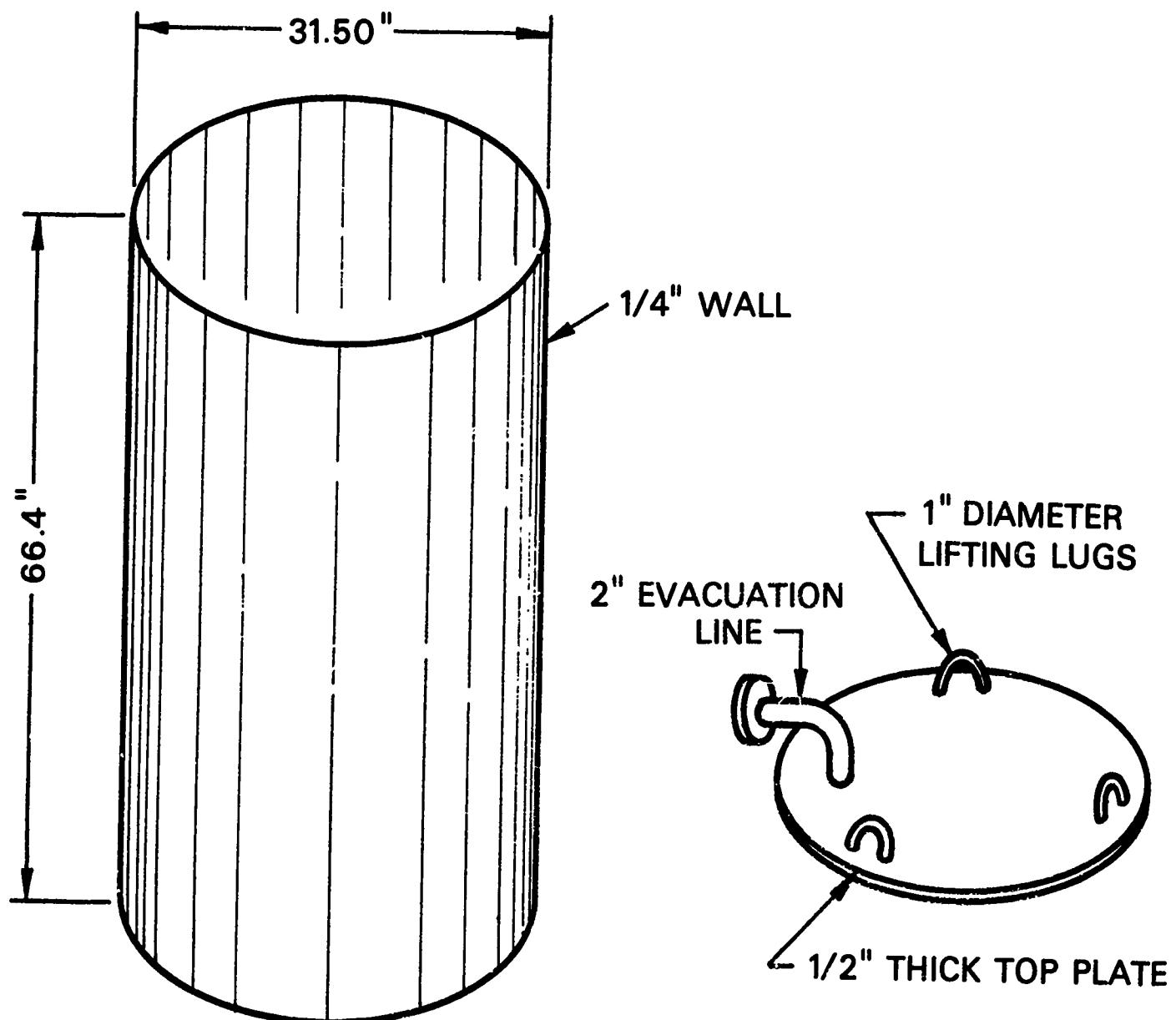
TABLE II  
POWDER SIZE FOR SCALE - UP ALLOY-POWDERS

Sample No.	Pot Number	Average Particle Diameter <sub>1</sub> μm	Average U.S. Standard Screen Analysis		
			-100 +200	-200 +325	-325
<u>MA87 Alloy</u>					
354107	1717	12.7	0.2	3.0	10.1
354108	1718	13.4	0.1	3.6	11.6
354109	1719	13.4	0.1	3.1	10.1
354110	1723	13.2	0.3	3.9	11.6
<u>MA67 Alloy</u>					
354111	1728	14.1	0.3	4.4	11.9
354112	1729	13.5	0.2	3.9	11.0
354113	1730	13.6	0.4	4.0	10.7
354114	1731	13.1	0.5	4.0	10.6
					84.9

Notes: 1. From Fisher Sub-Sieve Sizer  
2. All powder scalped through a 48 mesh screen (Tyler)



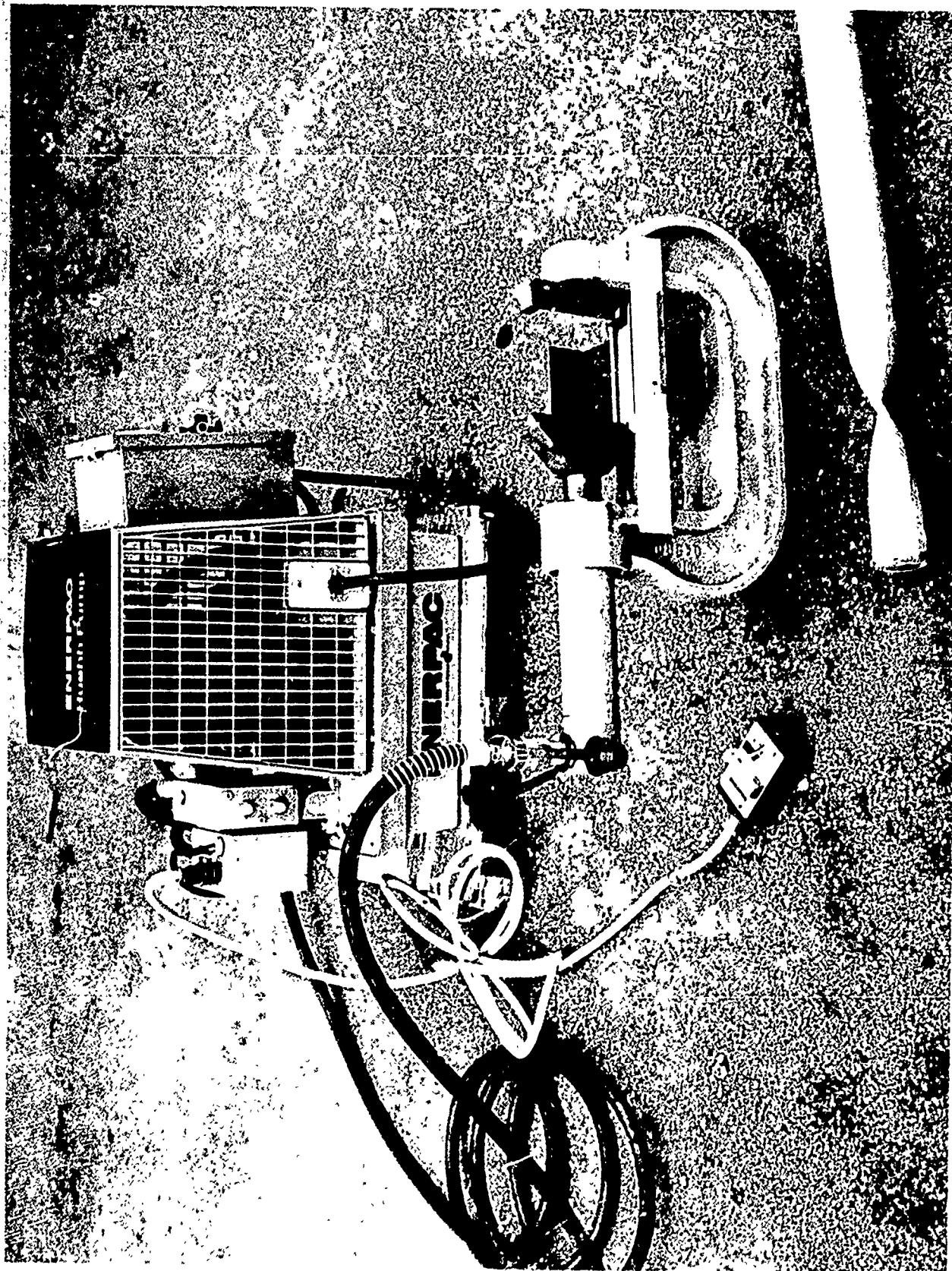
3100 LB. MA87 ALLOY ISOSTATIC COMPACT



SCHEMATIC OF POWDER PREHEAT CONTAINER

FIGURE 2

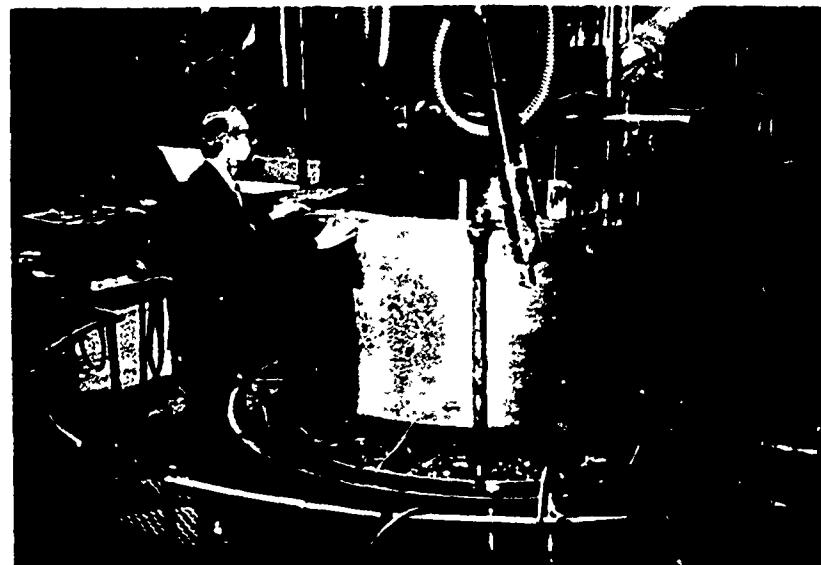
- 4 -



EVACUATION-LINE PINCH OFF TOOL ASSEMBLY.  
SHOWN WITH PINCHED 2" ALUMINUM PIPE.

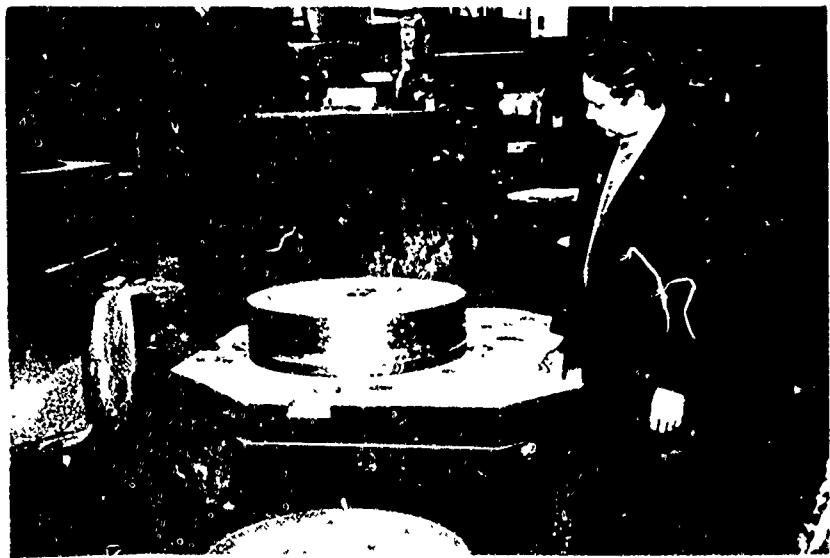


**COMPACTING CYLINDER LINER**



**COMPACTING CYLINDER  
OUTER CONTAINER**

**FIGURE 4**



5a

RAM NOSE PIECE

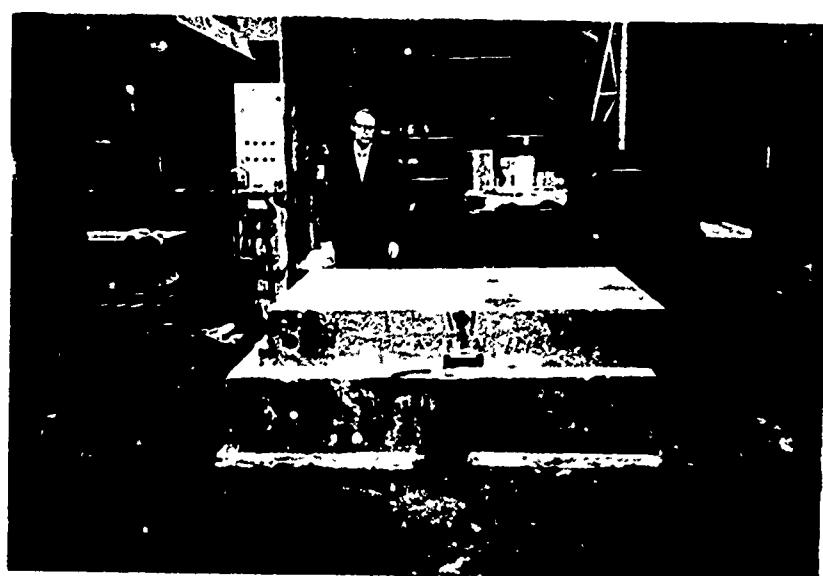


5b DENSIFICATION RAM



5c RAM HOLDER

FIGURE 5



**TOP AND BOTTOM HARD PLATES TO  
SECURE TOOLS TO PRESS PLATENS**

**FIGURE 6**



**BOTTOM SEAL FOR HOT COMPACTING CYLINDER**

**FIGURE 7**